Market Forecast for On-board and Co-packaged Optics

Summary of the report produced for ARPA-E

October 31, 2019

Study Objectives

Drivers: What is the motivation to move to more integrated modules? What are the benefits for customers? Why change?

Success factors: What factors are required for a broad-based movement to on-board and co-packed optics?

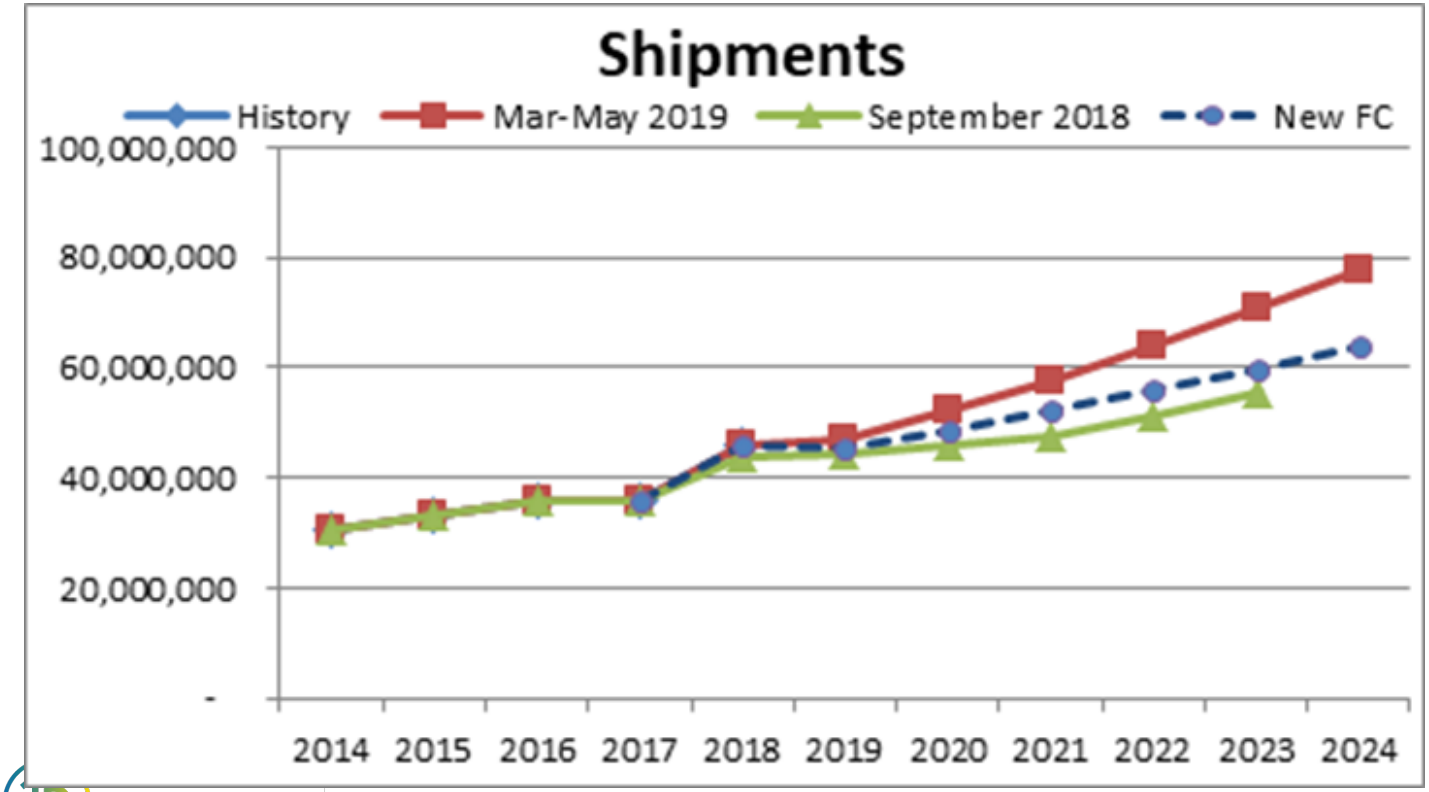
Barriers: What are some of the reasons on-board and co-packaged optics may not be adopted?

Recommendations on how to overcome the barriers
LightCounting will assess both the technology and business barriers for development of a robust and broad-based market for on-board and co-packaged optics.

Opportunity size for products related to its scope
LightCounting will perform market research to make estimates of types of modules consumed by data centers. This will include historical estimates for 2010-2018 and LightCounting projections for 2019-2028.

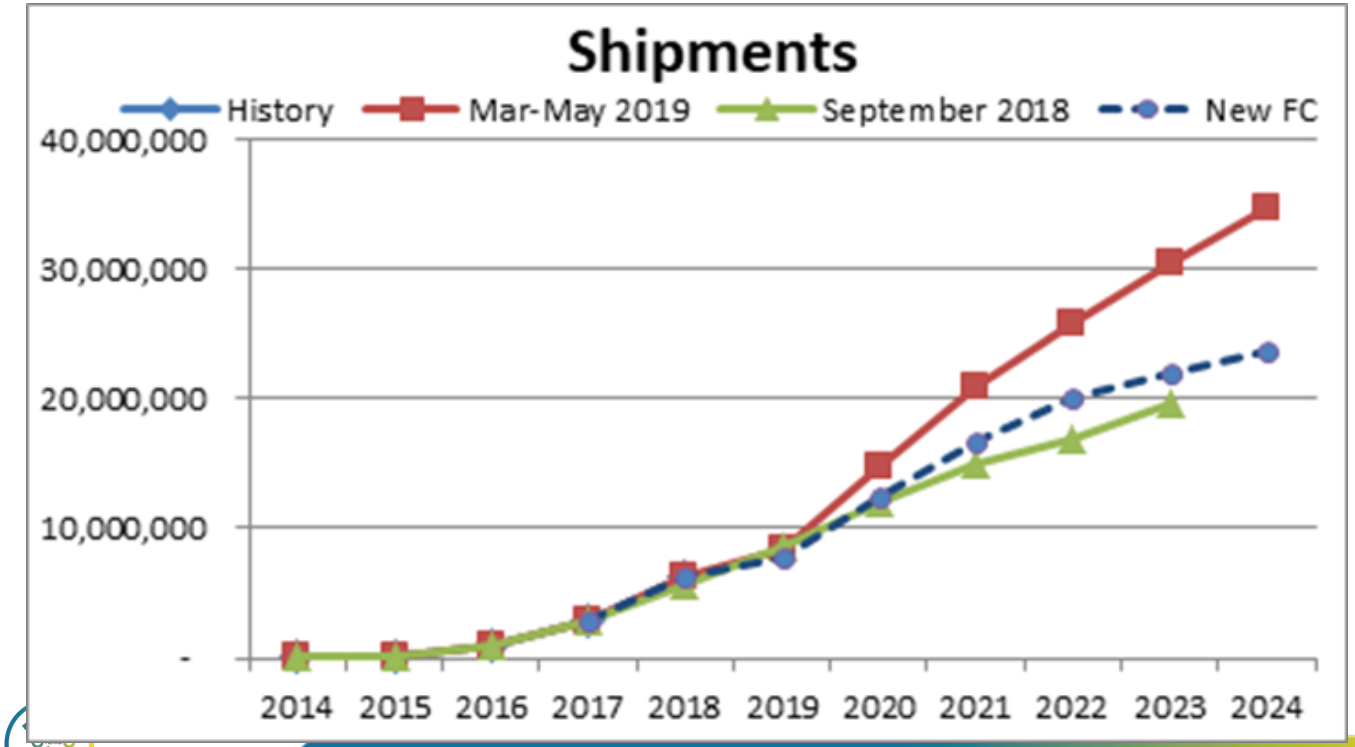
Part 1: Opportunity Size

The latest Forecast: Total Ethernet



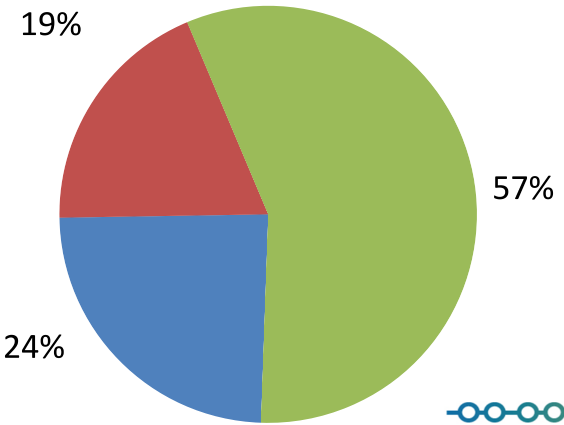
Changes in the Forecast: 100GbE only

Lowering projections for CWDM4 sub-spec and DR1s

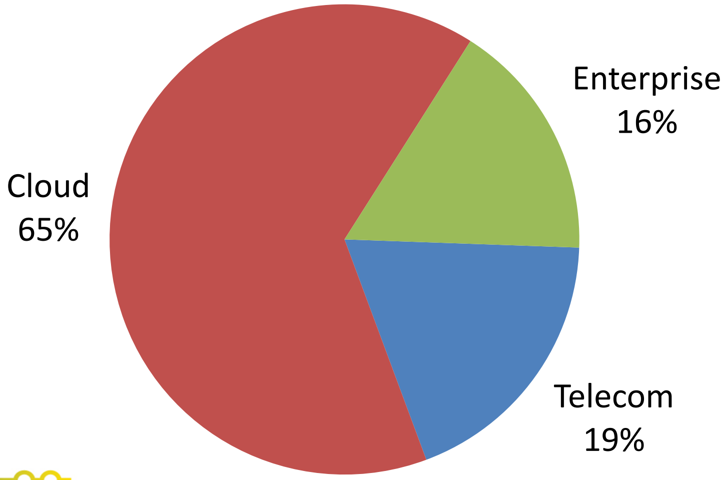


Ethernet transceiver sales by End User

2010 Ethernet revenue by segment
$0.5 billion

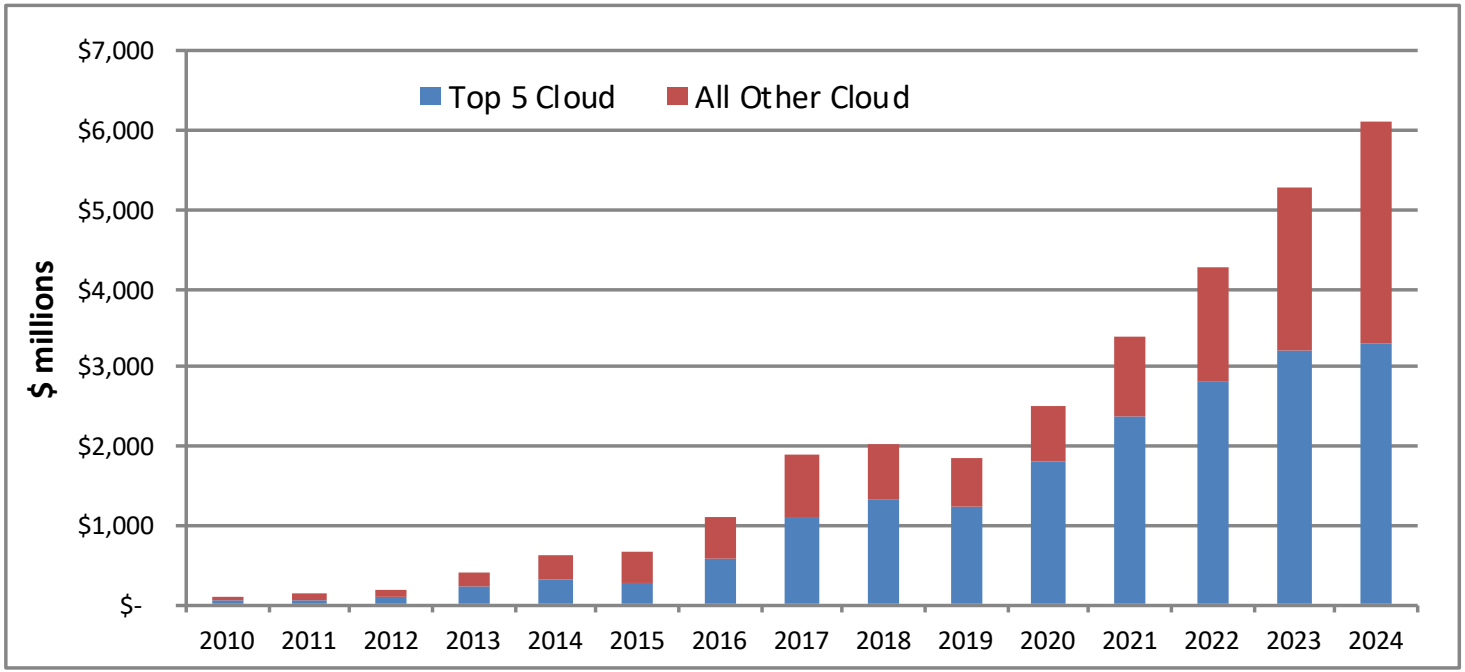


2018 Ethernet revenue by segment
$3.1 billion total



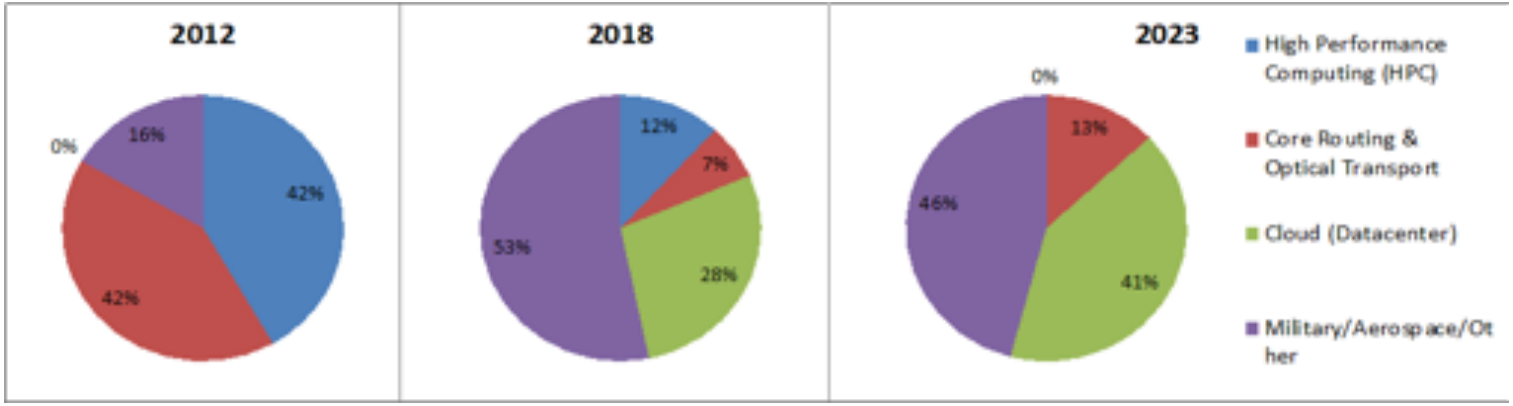
Sales of Ethernet to the Cloud

The all other category will grow faster in 2020-2024



Market for On-Board Optics (a.k.a. EOMs)

From LightCounting report on AOCs/EOMs published in December 2018



Total shipments in 2018 were about 300,000 units, forecast for 2023 is 700,000 units – a niche market.

COBO, supported by Microsoft will be 50% of this market segment by 2023 as long as Microsoft remains interested in an improved port density and operational benefits of COBO modules (these can be pre-installed by suppliers). An example of how one large customer can potentially change a market segment.

Part 1: Conclusions

1. Consumption of Ethernet optical transceivers is likely to exceed 100 Million Units per year before 2028.
    - Manufacturing, handling and installing such high number of modules is challenging, but it can be done. FTTH market is an example of such high volume market.
2. Majority of these devices will be operating at 100G and above. Deployments will be highly concentrated in very large mega DC clusters.
3. Top 5 customers account for the bulk of consumption today and it will not change significantly by 2028.
4. Optics will continue to replace copper as speed of connections increases.
5. Growth rate in bandwidth consumption will moderate from 50-100% per year today to 25-40% in 2024-2028.
6. Shipments of On-Board optics for mega DC (Cloud) applications will reach 300,000 units (50% of this niche market) by 2023, as long as Microsoft remains committed to the project.
7. Partnership of Facebook and Microsoft can launch a new market for co-packaged solutions.

Part 2: Drivers and Barriers

What is the motivation to move to more integrated modules? What are the benefits for customers? Why change?

Why change?

1. Very high volumes of optics: 100M units per year
2. High speed and complexity: 100Gbps and above
3. Multi-fiber connectors and multi-laser devices reduce reliability of optics
4. Concentrated deployment patterns: very large DCs and clusters
5. High power consumption limits scale of DCs
6. Interconnections with ASIC on-board becomes a problem at 200G signaling data rate
7. Face plate port density is reaching limits

Yet, the industry is determined to keep using pluggable optics as long as possible.

New integrated solutions have to offer significant advantages to gain traction.

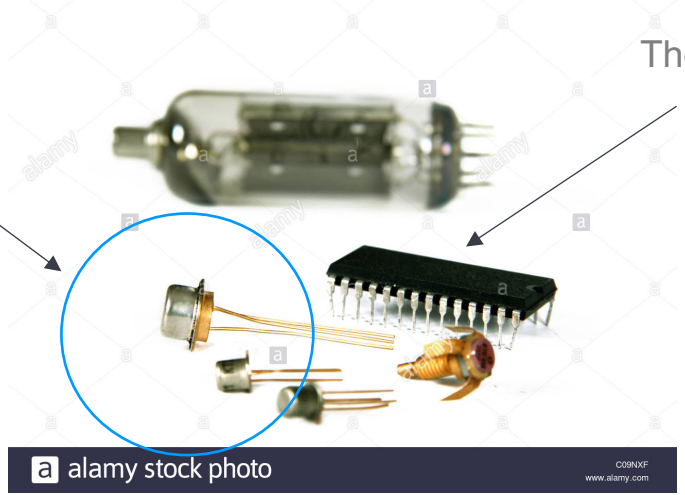
Can Silicon Photonics (SiP) change the market?

Moving from pluggable transceivers to highly integrated and co-packaged optics

The most advanced optics is getting here

Most of the optics is still there

SiP is used today to make pluggable, mostly 4-channel transceivers



Can the optics get to the next stage?

Part 2: Conclusions

Based on LightCounting interviews with the leading experts

The industry is not willing to change, at least not yet.

- The pluggable solutions are sufficient for the next 5-7 years, including 51Tbps switches
  - 50G signaling over copper on board is used now and it will support 100G per lane optics for 400GbE and 2x400GbE.
  - 100G signaling over copper on board works fine for a few inches with PAM4
  - 200G per lane optics can be accomplished with coherent DSPs
  - Liquid cooling can be used to resolve thermal management issues

- Keep on extending performance of existing technologies and using more power

However, demand for optics from Microsoft and Facebook is large enough to introduce new solutions.

Part 3: Success factors and recommendations

How to penetrate the market?

Connections in Mega Datacenters is the largest market opportunity, but these very large systems are unlikely to use new, unproved technologies. Unless Facebook and Microsoft are willing to take this risk.

HPC and AI clusters is a better option for entering the market. These systems are more open to innovation. FPGA chips may be the first to use co-packaged optics. Custom ASICs will be next.

Large players like Broadcom, Cisco, Huawei and Intel are likely to lead in adoption of on-board and co-packaged solutions, but they could use new optical technologies and probably developing them now.

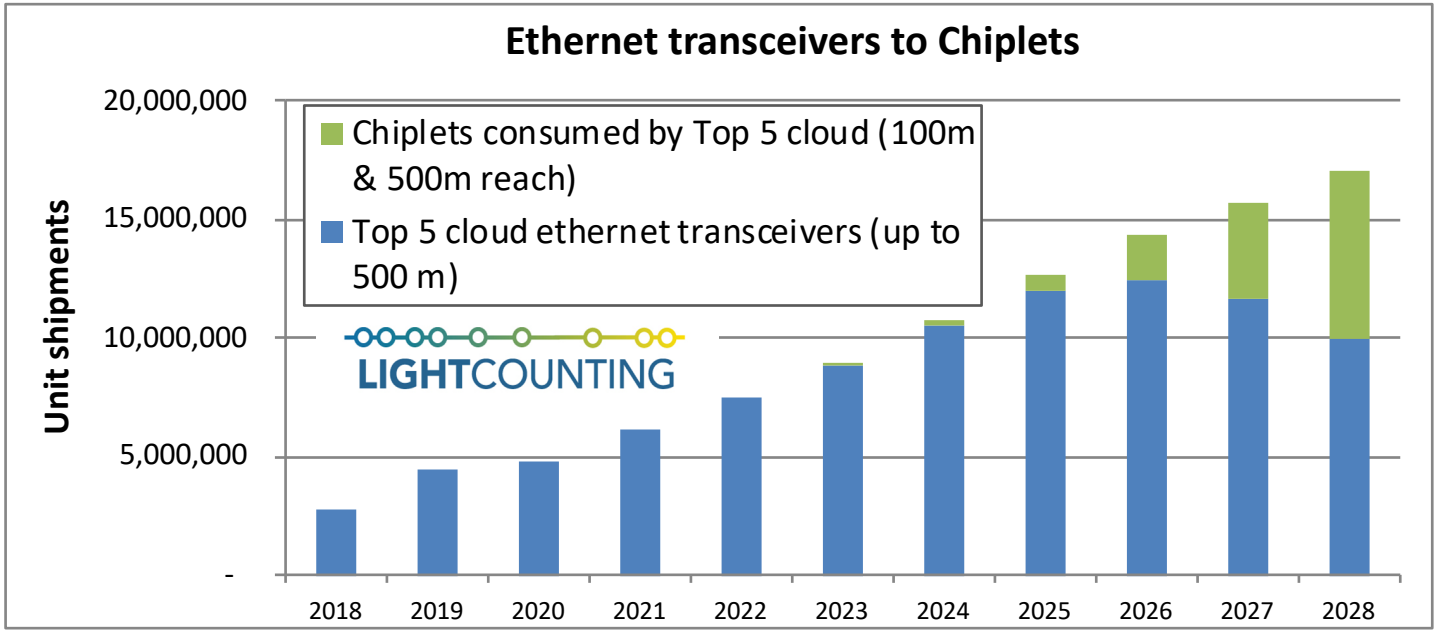
Optics remains the limiting factor for innovation in switching ASICs. Broadcom would love to change it by taking full control of the situation. Co-packaged optics is a great solution to this problem.

The best strategy for start-ups: work with a switch vendor.

Part 4: Market Forecast

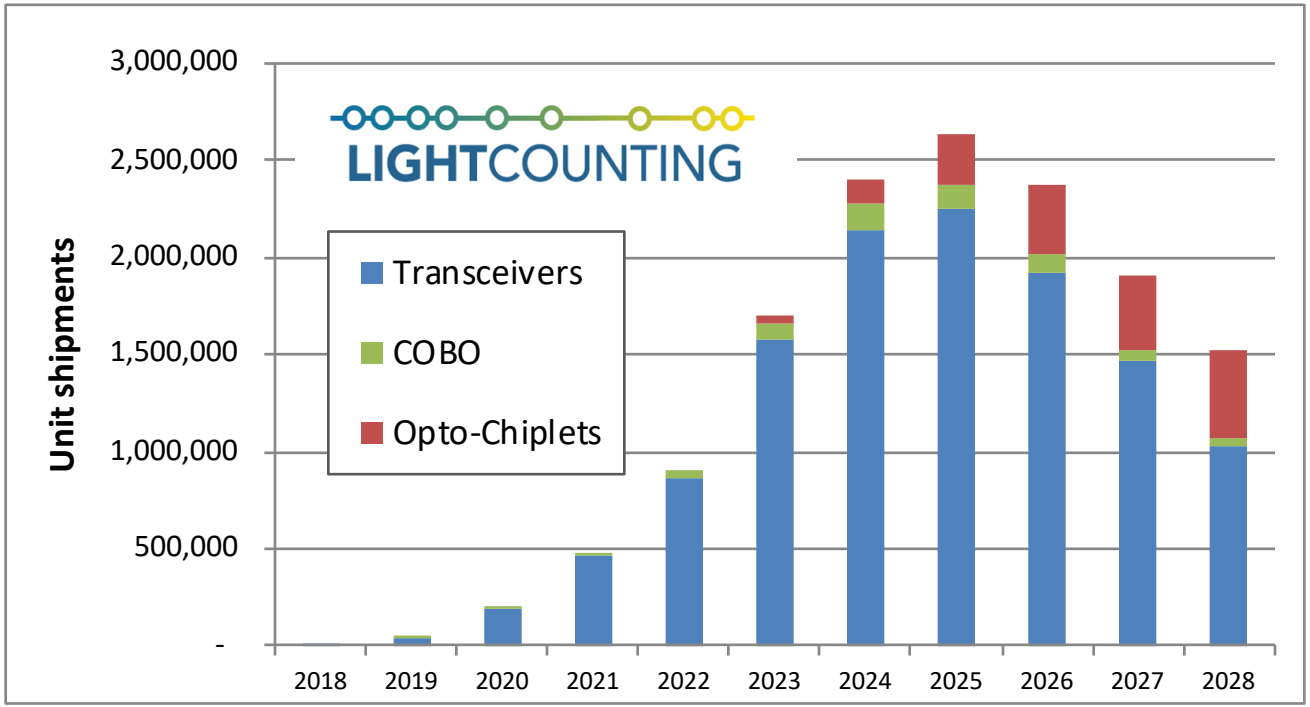
Transceivers and Chiplets for the Top 5 Cloud Companies

First optical chiplets will be deployed in 2023-2024, reaching high volumes in 2026-2028



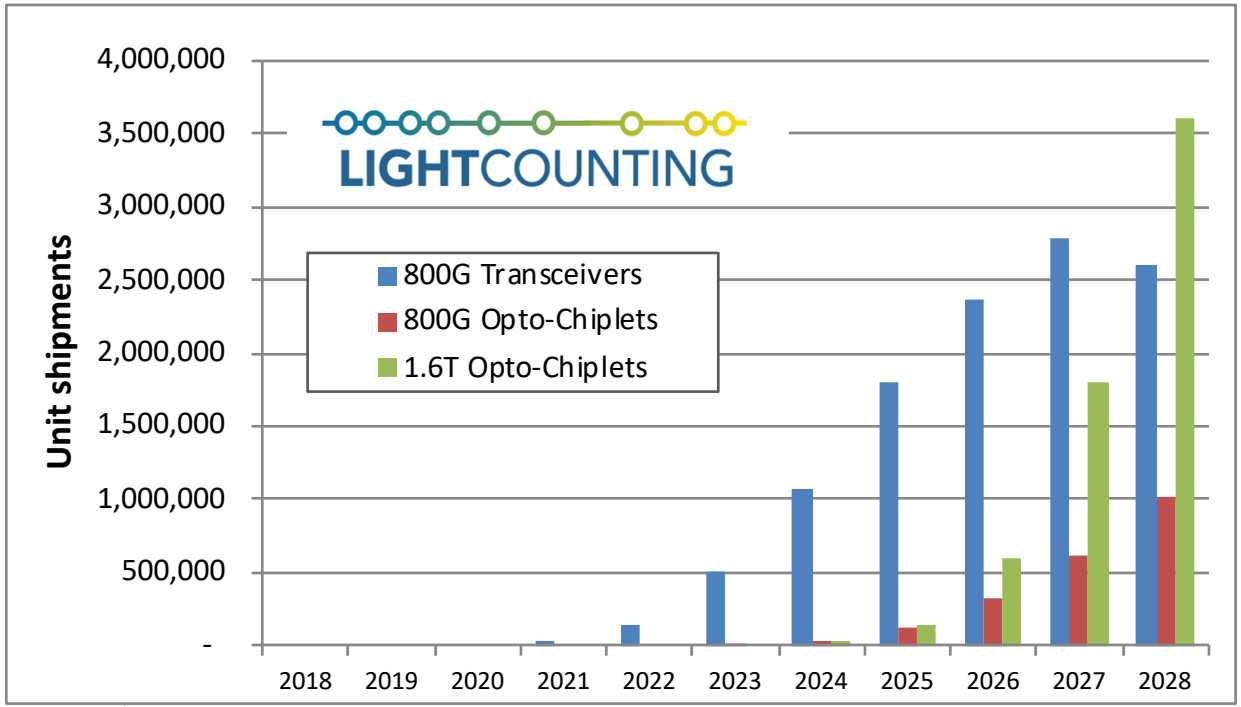
Adoption of chiplets starts with 400G, 500m reach

Microsoft remains committed to 400G COBO deployments



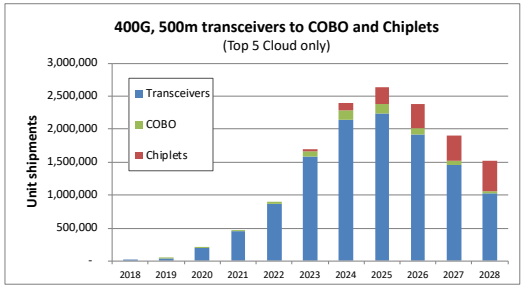
800G and 1.6Tbps Chiplets

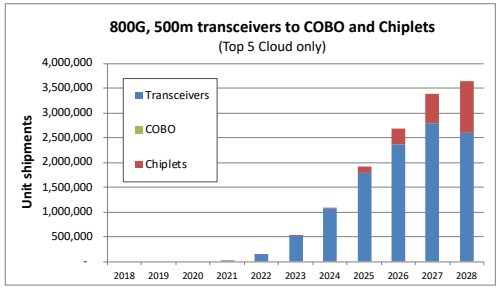
These will lag 400G by a year. No more COBO at these data rates

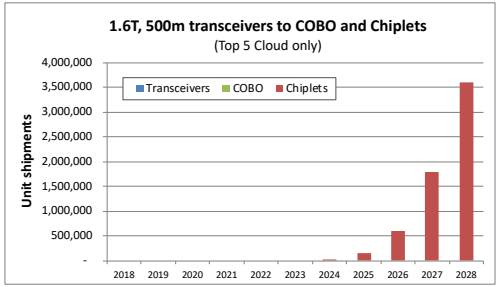


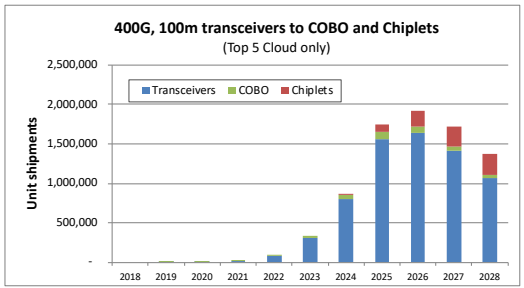
100m chiplets will lag 500m ones by a year

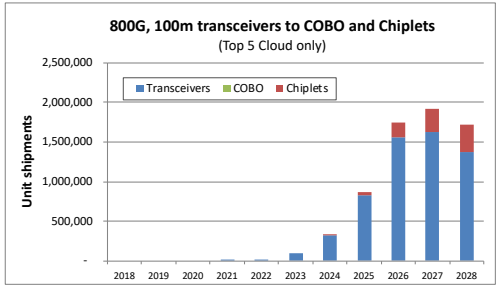
The unit volumes for 100m are 30% lower

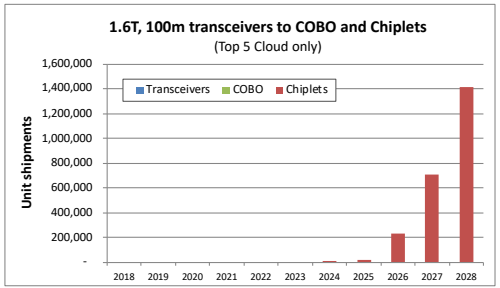






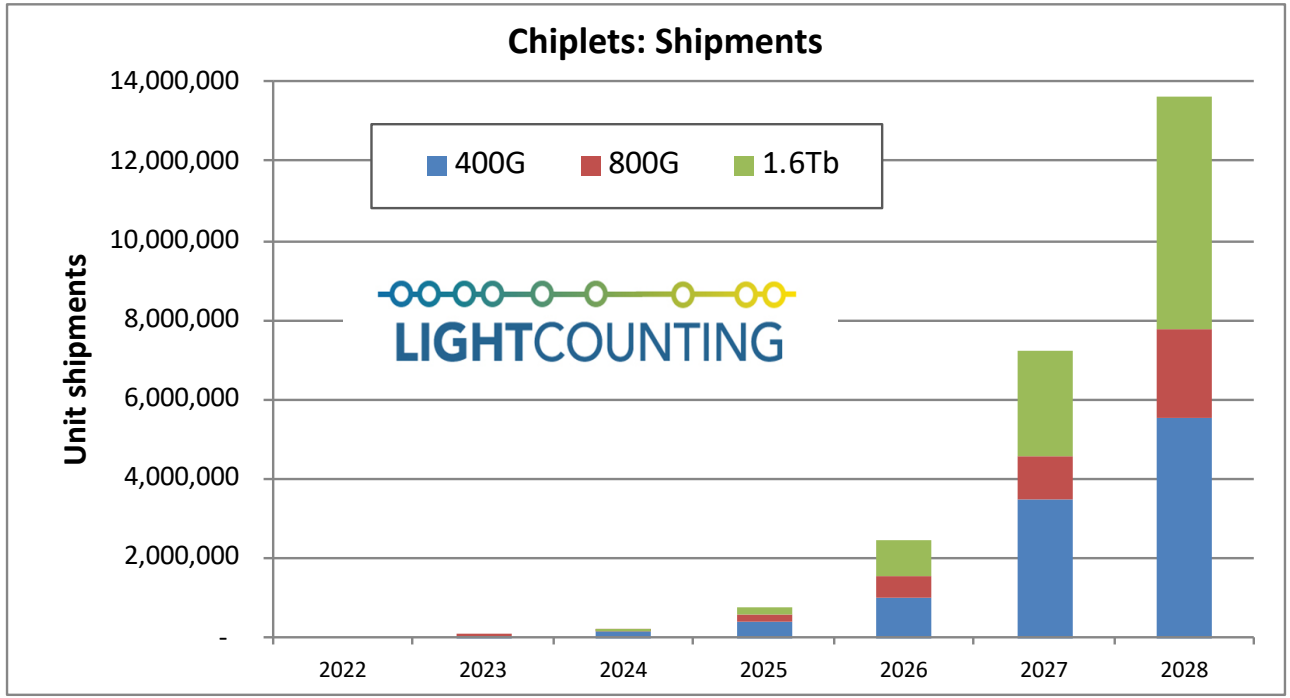






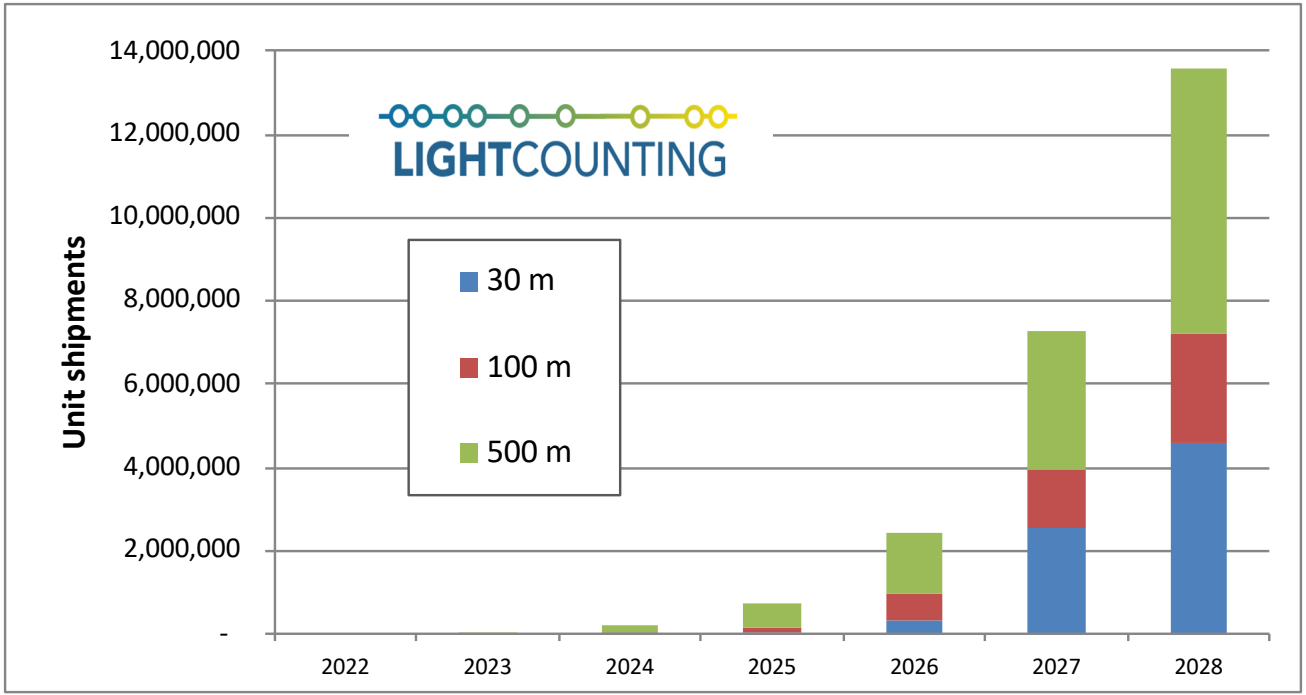
Optical Chiplets by Data Rate

This also includes 30m reach Chiplets, which will be mostly 400G



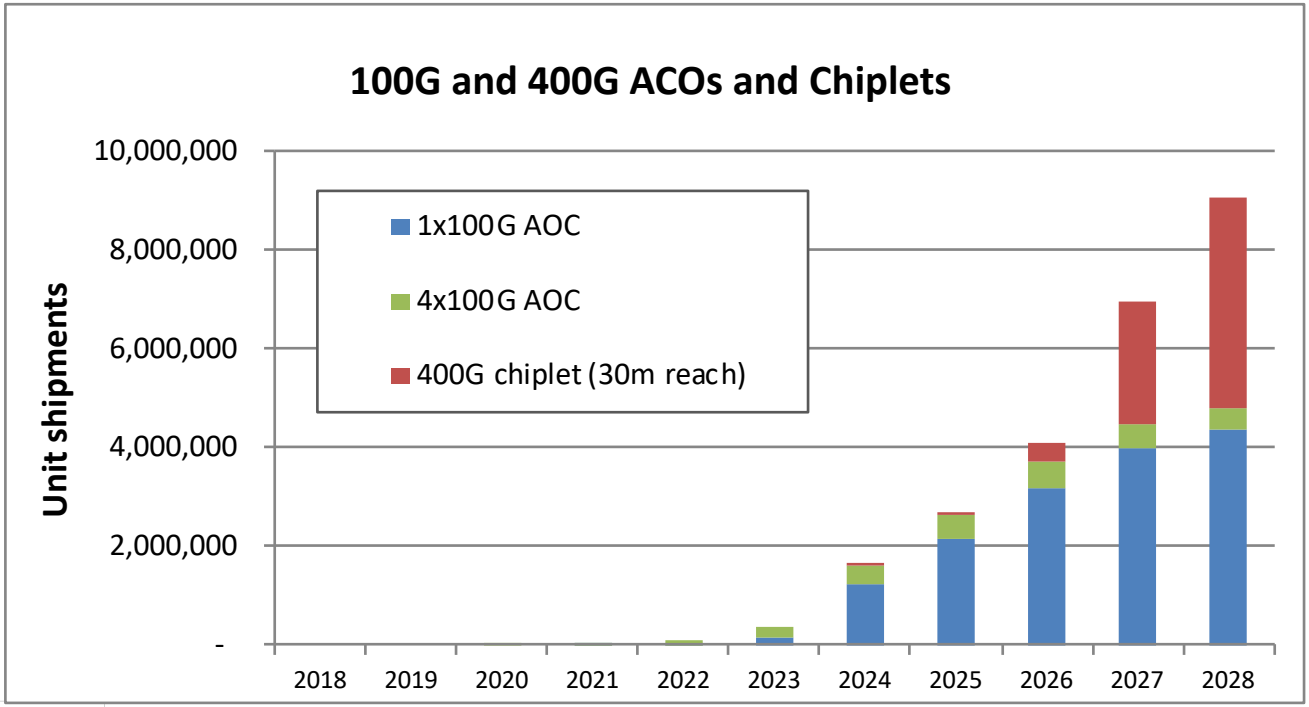
Optical Chiplets by Reach

100m reach will be a relatively low volume product as it replaces MMF transceivers



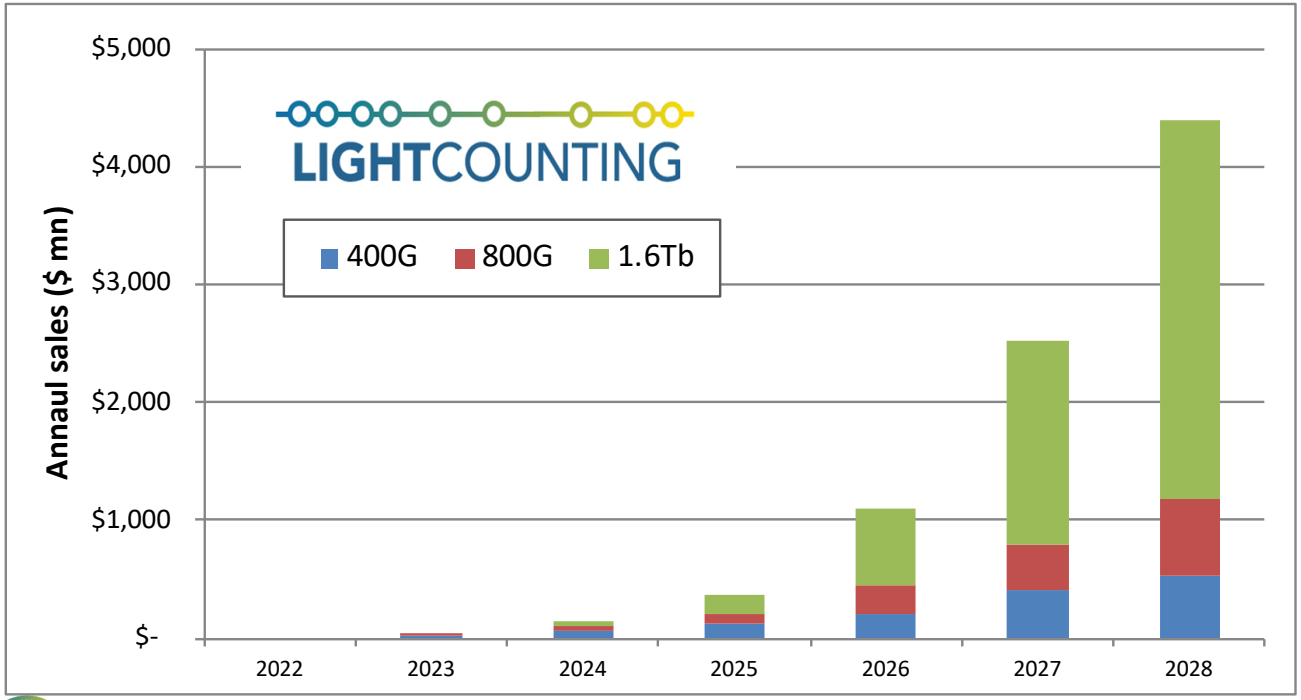
30m reach chiplets will replace 100G/400G AOCs

and copper cables. 800G 30m chiplets will start shipping in volume by 2028 as well.



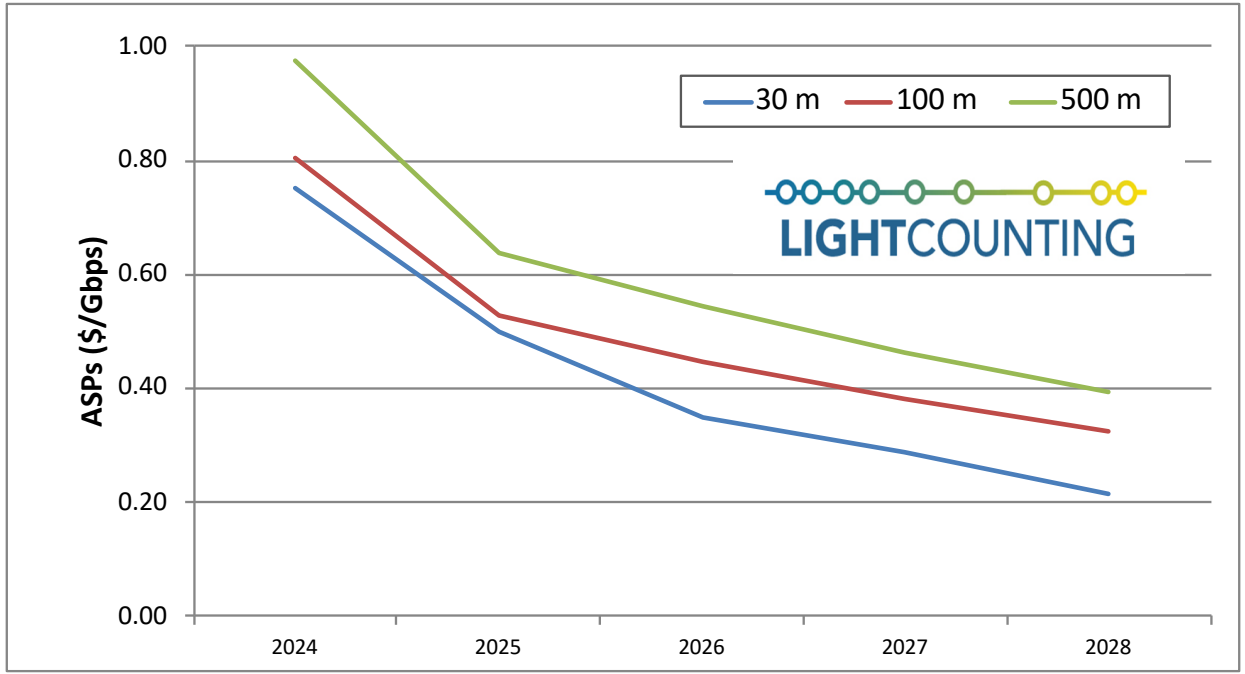
Estimating Sales of Optical Chiplets

However, many of these will be made internally by switch vendors and sold as part of switch ASIC (instead of being sold on a merchant market as optical chiplets)



Optical Chiplet Pricing ($/Gbps)

30m pricing needs to be higher in 2023-2026, 500m also needs to be higher in 2023



Pricing for 100m and 500m reach chiplets is based on prices of optical transceivers.

Pricing of 30m chiplets is based on prices of AOCs.

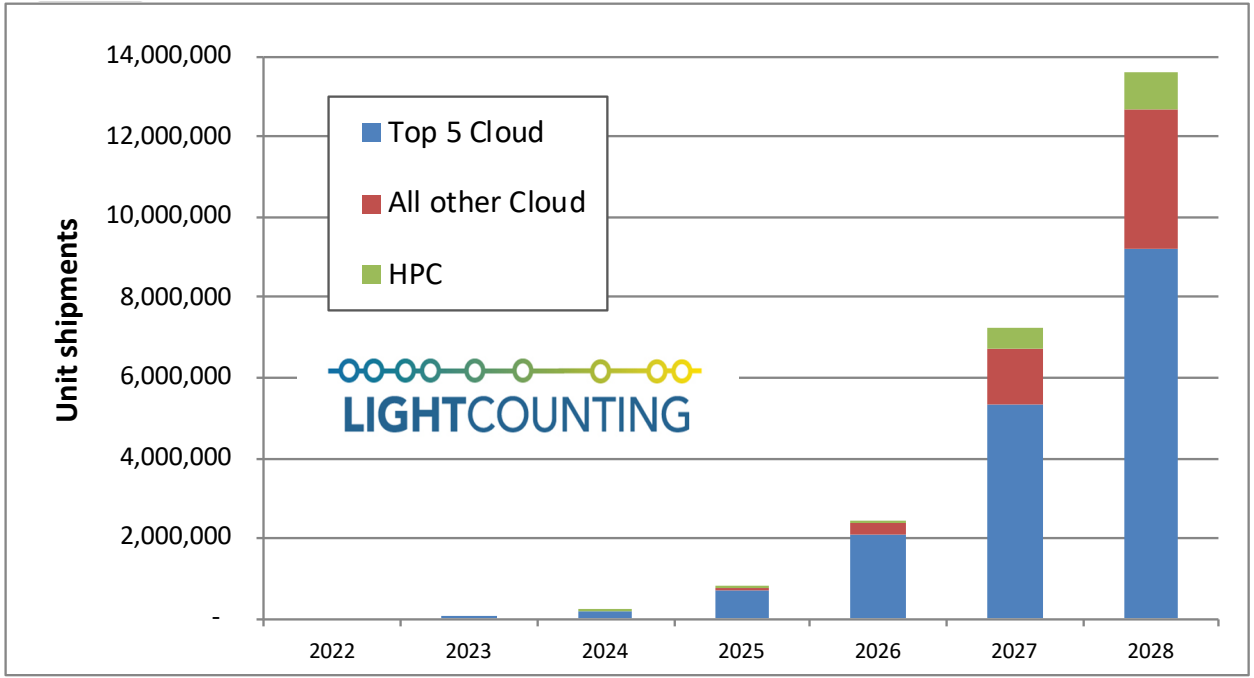
0.25$/Gbps = $100 for a 400G, 30m reach optical chiplet.

0.4$/Gbps = $640 for a 1.6Tbps, 500m reach optical chiplet.

A 51Tbps switch ASIC will need 32 of 1.6Tbps optical chiplets. This will add up to $20,500 in chiplets cost (assuming 500m reach).

Forecast Summary

The Top 5 Cloud companies will lead in adoption of co-packaging solutions



All Other Cloud companies will follow the Top 5 with a 2 year lag.

The volume of shipments to "All Other Cloud" will be similar to the "Top 5 Cloud".

High Performance Computers (HPCs) will be also important, but much smaller market opportunity for optical chiplets.

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Thank You